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Road Warrior

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To say that the monarch butterfly (*Danaus plexippus*) has fallen upon hard times is something of a colossal understatement. This butterfly's heroic annual migration from its eastern North American summer breeding grounds to a specific spot in the oyamel fir forests of mountainous central Mexico has been systematically monitored since 1995, and during the winter of 2013–2014 the population plummeted to an all-time low; the estimated 35 million butterflies represent a reduction of more than 97% relative to the peak size recorded in 1996. In view of the iconic status of the species, memorably dubbed "the Bambi of the insect world" by Iowa State University entomologist Marlin Rice (Weiss 1999), this dire decline was the motivation behind a petition submitted in August 2014 to the U.S. Fish and Wildlife Service and the Secretary of the Interior to list *D. plexippus* as a threatened species (http://bit.ly/1zS9CjB). The petition is a sad litany of not only the multitudinous natural shocks their flesh is heir to, including an assortment of predators and pathogens, but also a staggering array of unnatural shocks, including "pesticide use from genetically engineered, pesticide-resistant crop systems that kill milkweeds and nectar sources, as well as by development, logging, and climate change."

My first reaction on hearing about the petition, however, concerned another unnatural source of mortality that didn't make it onto the list, and it's one that might merit special attention given the peripatetic lifestyle of *D. plexippus*. The monarch wouldn't be the first widespread species that has been granted protected status—others already protected include the gray bat (*Myotis grisescens),* Indiana bat (*Myotis sodalis),* fat pocketbook mussel (*Potamilus capax*), and small whorled pogonia flower (*Isotria medeoloides*). All of these species, though, are a lot easier to look out for than are monarchs. Small whorled pogonia flowers stay firmly rooted to the ground, Indiana and gray bats spend a significant proportion of their time secreted in caves, and fat pocketbook mussels lie for most of their lives ensconced in their beds. Monarchs, however, have the disconcerting habit of playing in traffic across about a few thousand miles of North America.

At least in Illinois (where the monarch is officially designated as the state insect), when monarchs hit the road on that heroic migration, the road hits them back with a vengeance. I know this to be the case thanks to my former graduate student Duane McKenna, who, during his time at University of Illinois, partnered up with his undergraduate advisor Steve Malcolm at Western Michigan University to conduct what might have been the first

systematic Lepidoptera roadkill census in the United States (McKenna et al. 2002). It's more than a little surprising that the first such census didn't appear until motor vehicles had presumably been mowing down butterflies and other insects on American roads for almost 110 years (calculating back to the year that Frank and Charles Duryea founded the nation's first car, or, as known in that era, "motor wagon," manufacturing company).

The idea that vehicular traffic might cause significant mortality in species other than humans did not attract much attention from the scientific community for a surprisingly long time. According to Wikipedia, naturalist Joseph Grinnell is purported to have remarked in 1920 that death by automobile "is a relatively new source of fatality; and if one were to estimate the entire mileage of such roads in the state [California], the mortality must mount into the hundreds and perhaps thousands every 24 hours," but after several fruitless hours of searching, I couldn't find the original source of the quotation (although I did find an interesting paper that he had written in 1920 on dead seabirds found along ocean beaches following storms). Throughout most of the 20th century, the literature on the subject of roadkill is remarkably spotty, as it were. According to the Online Etymology Dictionary, the word "roadkill" wasn't even coined until 1972 (http://tinyurl.com/q797wpc). The etymologists evidently missed A.O. Haugen's 1944 paper, "Highway Mortality of Wildlife in Southern Michigan," which reports that "the lowest road kill noted in Ohio was 5.7 birds per 1,000 miles in September of 1938." Some variant of "road kill" also appears in J.R. Beer's 1948 "Notes on the Food Habits of Some Western Grouse," Hale's 1949 "Aging Cottontail Rabbits by Bone Growth," and the 1951 paper on "The Herpetology of the Mission Mountains, Montana" by R.B. Brunson and H. A. Demaree. The word even appears in the titles of the 1954 paper "A Study of Road Kills" by A.W Schorger in the journal *Passenger Pigeon* and the 1968 paper "Nocturnal Behavior in Iguanid Lizards and Possible Correlation with Roadkills" in the journal *Herpetologica* (Mays and Nickerson 1968). One of the masterfully understated conclusions of that last study of reptile roadkill, by the way, was that "Sleeping in the road can be dangerous."

Although "roadkill" is technically defined as an animal "killed by a vehicle on a road" (http://tinyurl.com/qzrpcbv), for the purpose of this discussion, "insect roadkill" comprises insects whose bodies are left on the road after being killed, in contrast with insects whose remains adhere to the offending vehicle (the subject of an earlier *Buzzwords* column [Berenbaum 2002]). That insects could be victims left in the roadway didn't even occur to most people. To his credit, Simmons (1938), in his book *Feathers and Fur on the Turnpike*, did remark that "Not many of us have gone so far as to determine whether the killing is confined to rabbits, skunks and an occasional game bird or whether it includes a cross-section of the entire wildlife population." I'm not sure who first attempted to quantify entomological roadkill, but my best guess is that it was Seibert and Conover (1991), who measured "Mortality of Vertebrates and Invertebrates on an Athens County, Ohio, Highway." The titular highway was a 1.6 km stretch of U.S. 33 around 10 km northwest of Athens, Ohio, which was surveyed 50 times between mid-June and mid-August and yielded over 1,000 insects representing minimally 249 species (minimally because "a number of specimens could not be identified to the specific level either because of their poor condition or the authors' lack of expertise") in 84 families in 11 orders. Of the 213 lepidopterans found dead, monarchs fared pretty well—only 2 of the 213 were danaids. Arctiid (48) and noctuid (71) moths were the biggest losers of life; among butterflies, 18 papilionids hit the pavement, almost double the number of the next-highest family fatalities (Nymphalidae).

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By 2014, in reviewing effects of roads on insects, Munoz et al. (2014) could only find about a dozen papers documenting collisions with insects of any kind. The studies are evenly divided between odonates and lepidopterans, and in the review the authors point out patterns that, in hindsight, probably shouldn't have been too surprising. With respect to Lepidoptera, sedentary species were road-killed less often than more mobile species, small butterflies were disproportionately road-killed relative to their numbers, species flying lower than 2 m above the ground experienced higher mortality than species flying more than 2 m above the ground, male mortality rates were higher than female mortality rates, and Lepidoptera experienced the highest mortality on Sundays (okay, that last one is kind of surprising).

Fourteen years later, McKenna et al. (2001) remains the definitive (and only) study of automobile-related monarch butterfly mortality. In this study, 1,824 road-killed Lepidoptera were found along 13 roadside transects in or around Urbana-Champaign, Illinois, during six weeks of collections. Traffic rates had an effect on butterfly mortality, with the greatest number of deaths occurring at intermediate traffic rates of 1,000, 13,500, and 19,700 vehicles per day per 100 m. Unexpectedly, at higher traffic rates, butterflies seemed to catapult over the car rather than collide with it. With respect to monarchs specifically, they were the second most frequently road-killed species, if *Colias eurytheme* and *Colias philodice* are lumped together (which they often were, as it turns out). A total of 99 were collected, including 55 males, 31 females, and 13 that couldn't be sexed due to damage to the relevant body parts. The highest number of monarchs collected per 100 m of transect occurred during the fourth week of sampling—6.5 at a traffic rate of 19,700 vehicles per day and 2.13 at a traffic rate of 13,500 vehicles per day—and the average number of monarchs collected per 100 m during the fourth week was significantly greater than the average number collected during the third, fifth, and sixth weeks. As it happened, the fourth week of the study coincided with the week of peak migration. Extrapolating these findings to the entire state (based on the total

number of miles of interstate, toll road, highway, county, municipal and other roads) puts the number of monarch butterflies killed in just one week in September on just Illinois roads at more than 500,000 individuals.

Needless to say, this is a pretty shabby way to treat a state symbol. In that respect, though, the monarch isn't alone—the white-tailed deer, *Odocoileus virginianus*, is the "state animal" of Illinois (yes, Illinois has a separate state animal, state bird, state insect, state reptile, and state amphibian, along with a state need for remedial taxonomy lessons for the state legislature). Hitting state symbols with automobiles appears to be a vibrant state tradition; in 2013, there were 15,328 deer/car collisions in the state, placing Illinois 31st in the country for deer collisions (Gregory 2014). I couldn't find the numbers, but I'm guessing that the painted turtle (state reptile) and the eastern tiger salamander (state amphibian) don't fare very well on Illinois roads, either. The only state symbol that's truly safe is probably the Tully monster, *Tullimonstrum gregarium* (the state fossil), if only by virtue of the fact that it went extinct 280 million years ago.

Nobody has checked roadsides for monarch corpses (or at least published on it) since 2002, but it's worth pointing out, as the petitioners do, "When crop fields had more milkweed in 1999, roadside plants accounted for only six percent of monarchs…Because of the decimation of cropland milkweed, roadsides now produce 35 percent of Midwest monarchs." The petitioners also cite the calculations of Flockhart et al. (2014) estimating that "roadside habitats now harbor 10 percent of all milkweeds in eastern North America." So, there are now more monarchs than ever living alongside the nation's roads. Will America be willing to restrict traffic to save migrating butterflies? There is a precedent—in Taiwan, there's a group of about 9 danaine species that migrate (Wang and Emmel 1990), although not as spectacularly as *D. plexippus*. In 2007, government officials in Taiwan closed a lane along a 600 m section near kilometer markers 251 and 253 of the Linnei section of Freeway No. 3, a major highway, to accommodate the 300 km migration of the "purple milkweed butterfly" (one of four, or possibly all four, species of *Euploea*), which at peak migration can pass through at rates of 11,000 per hour (http://bit.ly/1CybHDd). Ever since 2007, during peak migration, the Butterfly Conservation Society of Taiwan sets up nets on guardrails of the outer lane of the highway and then closes down the lane until the migratory flight is complete. Incidentally, the preparations coincide with the "Tomb Sweeping Festival" (http://bit.ly/1LQx5GF) between April and May.

So, maybe Illinois can be similarly convinced to close down roads during monarch migrations, to spare a half-million every year. Chicagoans must be accustomed to road closures—a visit to the City of Chicago "Today's Street Closures Listing" (http://bit.ly/1Ia1XT9) yielded 86 separate full street closures just for February 4 (and there's a separate listing for partial closures). That said, I don't know how well downstate residents will react. Certainly something has to be done if in fact the monarch is awarded threatened status. I've always been a nervous driver, but now I have to worry about accidentally hitting and killing a federally protected species while trying to find a parking place at Walmart. Irrespective of the outcome of the petition, maybe I should invest in an "I Brake for Insects" metal license plate frame (available at Amazon.com for only $10.95), or maybe that will just make things worse. During the course of a six-week study conducted by Arnold van Vliet in the Netherlands in 2010 (Messenger 2011), 17,836 dead insects were collected just from the front license plates of 250 participating automobiles.

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